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Natural Sciences

Original article

Tracing the past: The invasive marine gastropod *Eualetes tulipa* (Mollusca: Vermetidae) in the Colombian Caribbean

El rastro del pasado: el gasterópodo marino invasor *Eualetes tulipa* (Mollusca: Vermetidae) en el Caribe colombiano

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Abstract

The vermetid gastropod *Eualetes tulipa* (Rousseau, 1843) is recorded for the first time in the Colombian Caribbean. It is the second documented case of an invasive marine gastropod in the region. The species was observed in shallow waters on both artificial and natural substrates. Its identification was confirmed through morphological analysis (radula, operculum, and shell), molecular techniques (DNA barcoding), and historical records. Recent evidence of its presence in the Colombian Caribbean includes field photographs taken in 2016 at Isla Arena (Department of Bolívar) and Puerto Velero and its surroundings (Department of Atlántico). However, the invasion likely began earlier, with shells documented further northward from a nearby shipwreck at El Rodadero, Santa Marta (Department of Magdalena) as early as 1998. This timing is close to the first documented Caribbean record of the species in 1992 (Venezuela). The ecological impact of *E. tulipa* in the Colombian Caribbean remains unknown. Given the genetic similarity between the Colombian Caribbean specimens and individuals from Hawaii, our findings suggest a likely transoceanic introduction, potentially facilitated by maritime transport. Considering the extensive connectivity of international shipping routes, particularly those linking the Pacific and the Caribbean through the Panama Canal, it is important to monitor and manage *E. tulipa* as an invasive species. Its continued spread poses a significant threat to native biodiversity in Colombia and across the Caribbean region, especially in areas lacking biofouling regulations or early detection protocols.

Keywords: Integrative taxonomy; Threats to biodiversity; Non-native species; Fauna fouling; Gastropoda.

Resumen

Se registra por primera vez la presencia del caracol vermétido *Eualetes tulipa* (Rousseau, 1843) en el Caribe colombiano. Se trata del segundo caso documentado de un gasterópodo marino invasor en la región. La especie se observó en aguas someras, tanto en sustratos artificiales como naturales. Su identificación se confirmó mediante análisis morfológicos (rádula, opérculo y concha), técnicas moleculares (código de barras de ADN) y registros históricos. La evidencia reciente de su presencia en el Caribe colombiano incluye fotografías de campo que datan de 2016 en Isla Arena (departamento de Bolívar) y Puerto Velero y sus alrededores (departamento del Atlántico). Sin embargo, la invasión probablemente comenzó antes, con conchas documentadas en 1988 más al norte, en una nave hundida en El Rodadero, Santa Marta (departamento del Magdalena), fecha ésta cercana al primer registro documentado de la especie en el mar Caribe en 1992 (Venezuela). El impacto ecológico de *E. tulipa* en el Caribe colombiano es aún desconocido. Dada la similitud genética entre especímenes del Caribe colombiano y de Hawái, nuestro hallazgo sugiere una probable introducción transoceánica, posiblemente facilitada por el transporte marítimo. Considerando el alto tráfico marítimo entre el Pacífico y el Caribe a través del Canal de Panamá, se subraya la importancia del monitoreo y la gestión de *E. tulipa* como especie invasora. Su continua propagación representa una amenaza significativa para la biodiversidad nativa en Colombia y en toda la región del Caribe, particularmente en zonas que carecen de regulaciones contra la bioincrustación o protocolos de detección temprana.

Palabras clave: Taxonomía integrativa; Amenazas a la biodiversidad; Especies no nativas; Incrustaciones de fauna; Gastropoda.

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Introduction

An introduced species is one that has been transported from its native geographical range to a new location by human activities and has established self-sustaining populations (**Carton & Schwindt**, 2025). Once established, these species tend to spread aggressively, causing harm to the environment, infrastructure, human health, or the economy. According to the 2010 Convention on Biological Diversity Conference of the Parties (COP10), invasive species are globally considered the second leading cause of native species extinction.

A comprehensive synthesis of non-native mollusk species in South America (**Darrigran *et al.***, 2020) identified 86 species distributed across 152 of the 189 recognized ecoregions. Of these, 14 species inhabit marine environments. Compared to marine bivalves, gastropods are less represented among invasive mollusk species. **Darrigran *et al.*** (2020) included a few notable families: Haliotidae, represented by *Haliotis discus hannai* Ino, 1953, and *H. rufescens* Swainson, 1822; Muricidae, by *Rapana venosa* (Valenciennes, 1846), and Pleurobranchaeidae, by *Pleurobranchaea maculata* (**Quoy & Gaimard**, 1832), all of which have been recorded in south-central South America. Vermetidae was also included, represented by *Eualetes tulipa* (**Rousseau**, 1843), the first invasive gastropod recorded in the Caribbean, reported as *Vermetus* sp. by **Miloslavich and Penchaszadeh** (1992). **Darrigran *et al.*** (2020) recorded as well Cypraeidae, represented by *Naria turdus* (Lamarck, 1810), first documented in Aruba between 2019 and early 2020 (**Oleinik** 2023). Since then, *N. turdus* has been observed in Bonaire, Curaçao, Venezuela, Costa Rica, the Cayman Islands, Puerto Rico, West Palm Beach (USA), Florida (USA), and Colombia (**Dekkers & Ros**, 2022; **Oleinik**, 2023; **Oleinik *et al.***, 2023; **Gracia *et al.***, 2024).

To date, five invasive marine and brackish mollusk species have been recorded in Colombia (**Gracia *et al.***, 2011; **Gracia *et al.***, 2024): the bivalves *Electroma* sp., *Corbicula fluminea* (O. F. Müller, 1774), *Perna perna* (**Linnaeus**, 1758), *P. viridis* (Linnaeus, 1758), and the gastropod *N. turdus*. However, the only marine mollusk species officially recognized as exotic invasive in Colombia by the Ministry of Environment and Sustainable Development, under Resolution 0067 of 2023, is *Electroma* sp.

Family Vermetidae consists of tube-building, suspension-feeding organisms comprising at least 171 extant species (**WoRMS**, 2025; accessed 30/May/2025). This family is characterized by a sessile life, with individuals attaching their shells to substrates. Their shells are irregularly coiled, and the group is predominantly found in warm temperate and tropical oceans worldwide (**Keen**, 1971; **Golding *et al.***, 2014). In the Colombian Caribbean, the Vermetidae comprises three genera and five documented species, including *Thylacodes decussatus* (Gmelin, 1791), *Petaloconchus erectus* (Dall, 1888), *Petaloconchus varians* (A. d'Orbigny, 1839), *Dendropoma corrodens* (A. d'Orbigny, 1841), and *Petaloconchus* sp. 1.

To clarify the taxonomic status of some vermetid specimens found attached to artificial and natural hard substrates in the Colombian Caribbean Sea, here we sought to resolve their taxonomic identity at the species level using anatomical and shell characteristics, as well as molecular data.

Material and methods

Study area

The study was primarily conducted at the Puerto Velero Marina (PVm), on the sheltered side of the Puerto Velero sand spit in the Department of Atlántico, Caribbean coast of Colombia (**Figure 1**). Some specimens were collected from very shallow rocky areas (live specimens: Caño Dulce) and empty shells found on the beach (Puerto Caimán), located nearby and to the south of the PVm (**Figure 1**). Photographic reference material from the departments of Bolívar and Atlántico, along with shell specimens collected in Rodadero (Department of Magdalena), was also used to ensure coverage across the central Colombian Caribbean (**Figure 1**).

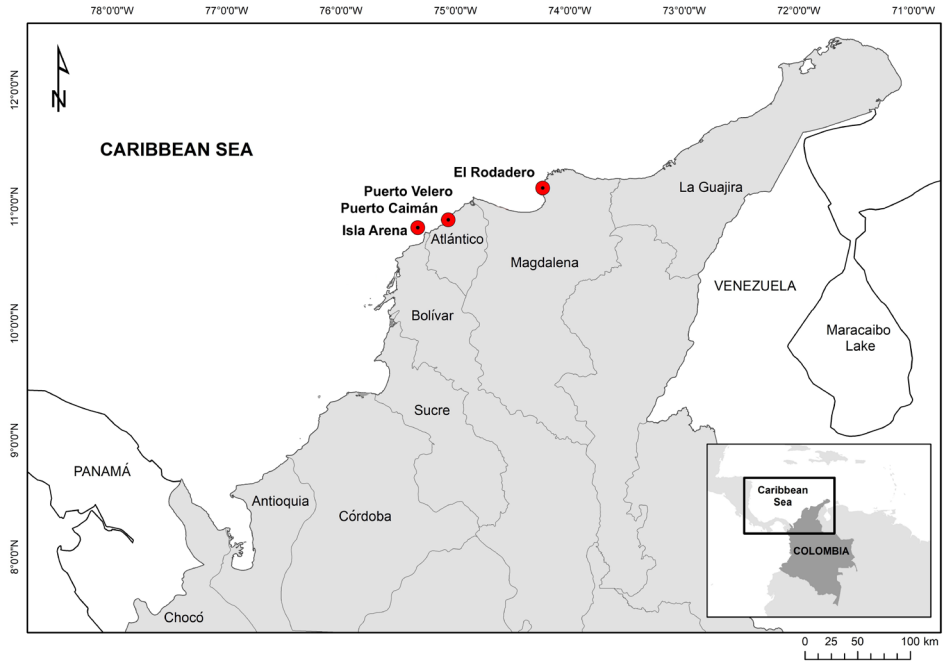

Figure 1. Locations where *Eualetes tupila* has been recorded in the Colombian Caribbean Sea

The climate in this part of the Colombian Caribbean is characterized by a dry season from December to April, a rainy season from August to November, and a transitional period between these seasons from May to July (**Rangel-Buitrago *et al.*,** 2016). During the dry season, Caribbean currents are driven by northeast winds, creating a southwest coastal current (**Rangel-Buitrago *et al.***, 2016) that brings significant sediment inputs from the Magdalena River (**Pujos *et al.***, 1986). In the rainy season, when the southeast Darién current intensifies, the transport of sedimentary material from the Magdalena River plume along this coast decreases (**Rangel-Buitrago *et al.***, 2016), despite the increased sediment discharge from the river (**Pujos *et al.*,** 1986; **Posada & Henao**, 2008). Tropical depressions during the rainy season can sometimes develop into hurricanes, which can produce sediment transport in a southwest direction, potentially affecting the study area's coastline (**Rangel-Buitrago *et al.***, 2016). The tides are mixed semi-diurnal, with maximum amplitudes of 65 cm (**Torres & Tsimplis**, 2012).

PVm is considered a small-to-medium marina, which serves as a stopover for vessels navigating between other marinas in the broader Caribbean region, primarily receiving boats from the United States and Europe. PVm, Caño Dulce, and Puerto Caiman are located in an area with high sedimentation due to their proximity to the Magdalena River delta. The annual suspended sediment load has been estimated at $145 \pm 47 \times 10^6$ t year $^{-1}$ (**Higgins *et al.***, 2016), plus sediment inputs of 26 micro-basin streams that discharge into the sea along the coastline (**Rangel-Buitrago *et al.***, 2020).

Revised material

Living specimens were collected at depths of 0.1–0.5 m from concrete slabs that form the main framework of the PVm (10°56'42.25"N; 75°2'28.66"W). Randomly selected animals attached to well-lit surfaces (1.85 × 0.5 m) of the central corridor were collected by snorkeling, using a chisel. The material included specimens collected in 2019 for shell and morphological analysis, and in December 2024 for DNA extraction. Specimens intended for shell and morphological analysis were fixed in 75% ethanol, while organisms for molecular analysis were anesthetized using menthol diluted in seawater and subsequently fixed in 96% ethanol. Empty shells found on the beach of Puerto Caimán (10°55'22,20"N;

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75°2’3,05”W) were also reviewed. Empty vermetid shells attached to a shell of *Spondylus americanus* Hermann, 1781, collected around 1998 from a shipwreck (11°12’39.12”N; 74°14’18.08”W) at a depth of 30 m off El Rodadero (Santa Marta) (**Figure 1**), were included in the study.

The gastropod was identified to the lowest taxonomic level, following the guidelines of **Spotorno-Oliveira *et al.*** (2018) and **Tan *et al.*** (2021). For detailed examination, a radula and eggs of *E. tulipa* were observed using a Hitachi SU3500 scanning electron microscope (SEM). The voucher material was deposited in the Museo de Historia Natural Marino de Colombia - Makuriwa (Santa Marta), under the acronym INV MOL.

Molecular analysis

Eight specimens of *E. tulipa* collected in PVm were used for DNA analysis (INV MOL12877 to INV MOL12884). DNA barcoding was conducted on foot tissue samples preserved in absolute ethanol. DNA was extracted using the CorpoGen DNA2000 kit, with a protocol involving tissue maceration (250 mg) and proteinase K digestion. High concentrations of salts were used to precipitate proteins, and isopropanol to precipitate DNA. Finally, the samples were resuspended in 50 µl of elution buffer. The mitochondrial COI gene was amplified by PCR using the universal primers LCO1490 and HC02198 (**Folmer *et al.***, 1994). PCR optimization determined 40°C as the most suitable annealing temperature, though successful amplification of *E. tulipa* samples also occurred at 50°C. Amplified products were sequenced using the Sanger method with both primers. The resulting sequences were assembled into contigs where possible, and then taxonomically identified using the BOLD Systems Identification Engine and NCBI BLAST. The sequences generated were deposited in GenBank under the accession numbers PZ038916to PZ038922 (**Table 1**).

Results

A total of 15 lots, each with a different number of individuals, from three southern locations (PVm, Caño Dulce, and Puerto Caimán) and one northern location (El Rodadero, shells only) were examined and identified. The morphological and DNA barcoding information confirmed the identity of the species *E. tulipa* in the Colombian Caribbean.

The following is the taxonomic information following the classification of **WoRMS** (2025):

Phylum Mollusca

Class Gastropoda Cuvier, 1795

Subclass Caenogastropoda L. R. Cox, 1960

Order Littorinimorpha A. N. Golikov & Starobogatov, 1975

Superfamily Vermetoidea Rafinesque, 1815

Family Vermetidae Rafinesque, 1815

Genus *Eualetes* Keen, 1971

Eualetes tulipa (Rousseau, 1843) (**Figure 2** a–m; **Figure 3** a–n)

Examined material: 20 shells INV MOL12706 (27/Dec/2019, attached to concrete slabs - atcs - PVm) collected on the beach after PVm wall substrates replacement; 13 empty shells INV MOL12713 (18/Feb/2024, attached to woody debris, barnacles and bivalve shells in Puerto Caimán) shells found on the beach after extreme wave event; 1 empty shell INV MOL12714 (18/Feb/2024, attached to *Strombus pugilis* Linnaeus, 1758 in Puerto Caimán, on the beach); 1 specimen INV MOL12871 (2/Nov/2024, attached to a rock, 0.3 m depth, Caño Dulce); 1 specimen INV MOL12877 (5/Dic/2024, atcs, 0.3 m, PVm); 1 specimen INV MOL12878 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen INV MOL12879 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen INV MOL12880 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen + eggs INV MOL12881 (5/Dec/2024, atcs, 0.3 m, PVm);

Table 1. Information of the *Eualetes tulipa* specimens studied along the Colombian Caribbean coast. Apertural diameter: AD; Operculum diameter: OD; Substrate: Artificial: A; Stored material: Dry: D or Humid: H. The number of specimens indicates the apertural tubes that were counted and measured; in some aggregations of organisms, it was not possible to individualize.

Catalog number	N° of specimens	AD (mm)	Height/ width (mm)	OD (mm)	Substrate	D/H	GenBank accession numbers COI
INV MOL12706	1 apertural tube	9.49	37.16/49.77	-	A	H	
	7 apertural tubes (aggregated)	7.38; 8.74; 8.07; 9.74; 8.86; 8.86; 7.18	-	-	A	H	
	10 apertural tubes (aggregated)	8.14; 7.29; 8.08; 7.35; 6.25; 8.88; 6.45; 9.16; 9.54; 8.00	-	-	A	H	
	2 apertural tubes (aggregated)	9.58; 8.45	18.29/48.95	5.31/-	A	H	
INV MOL12713	2 apertural tubes (aggregated)	6.99; 3.32	-	-	On bivalve shell	D	
	3 apertural tubes (aggregated)	8.62; 9.77; 4.19	-	-	On barnacles and bivalves	D	
	8 apertural tubes (aggregated)	5.18; 4.02; 3.20; 3.27; 4.22; 3.66; 5.10; 4.93	-	-	On woody debris	D	
INV MOL12714	1 apertural tube	5.55	24.24/26.32	-	On *Strombus pugilis*	D	
INV MOL12871	1 apertural tube	6.11	12.08/24.64	-	On a rock	H	
INV MOL12877	1 apertural tube	Broken	-	4.06	A	H	PZ038916
INV MOL12878	1 apertural tube	7.63	39.17/28.08	4.25	A	H	PZ038917
INV MOL12879	1 apertural tube	Broken	-	3.5	A	H	PZ038918
INV MOL12880	1 apertural tube	7.54	24.12/29.94	4.25	A	H	PZ038919
INV MOL12881	1 apertural tube	7.95	29.76/31.13	4.43	A	H	PZ038920
INV MOL12882	1 apertural tube	9.39	32.45/37.35	4.75	A	H	
INV MOL12883	1 apertural tube	Broken	14.91/28.00	Broken	A	H	PZ038921
INV MOL12884	1 apertural tube	6.75	48.05/22.81	5.43	A	H	PZ038922
INV MOL12886	1 apertural tube	9.01	36.82/32.23	-	A	H	
	1 apertural tube	8.96	27.31/43.14	-	A	H	
	1 apertural tube	7.19	42.52/28.95	-	A	H	
	1 apertural tube	7.47	32.12/32.00	-	A	H	
	1 apertural tube	5.45	29.20/27.93	-	A	H	
	1 apertural tube	8.65	21.39/29.68	-	A	H	
	1 apertural tube	8.78	30.45/31.84	-	A	H	
	1 apertural tube	5.97	38.18/23.94	-	A	H	
INV MOL12885	8 apertural tubes	7.36; 6.46; 5.75; 6.99; 5.41; 4.9; 6.46; 5.72	41.70/29.47 27.96/26.76 18.77/28.76 25.55/22.41 20.79/13.24 - 23.35/30.24 13.22/26.47	-	A	H	
INV MOL12887	1 apertural tube	4.54	13.63/20.07	-	A	D	
MOL-396	1 main apertural tube plus seven small tubes	7.76	10.91/44.81	-	On *Spondylus americanus*	D	

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1 specimen + eggs INV MOL12882 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen INV MOL12883 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen INV MOL12884 (5/Dec/2024, atcs, 0.3 m, PVm); 8 specimens INV MOL12885 (5/Dec/2024, atcs, 0.3 m, PVm); 8 specimens INV MOL12886 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen INV MOL12887 (5/Dec/2024, atcs, 0.3 m, PVm); 1 specimen (+7 small ones) MOL-396 attached to *S. americanus* shell (collected around 1998 from a shipwrecks at a depth of 30 m off El Rodadero, Santa Marta).

Diagnosis: Sessile gastropods were observed as solitary individuals (**Figure 2 a–b**) or in groups (**Figure 2 c**), attached to both natural and artificial substrates. The shell is elongated, forming irregularly coiled tubes, predominantly white with variable brown streaks. The maximum apertural diameter recorded was 9.77 mm (**Table 1**). Juvenile shells are uniformly darker, displaying a reddish-brown coloration (**Figure 2 d**). The head-

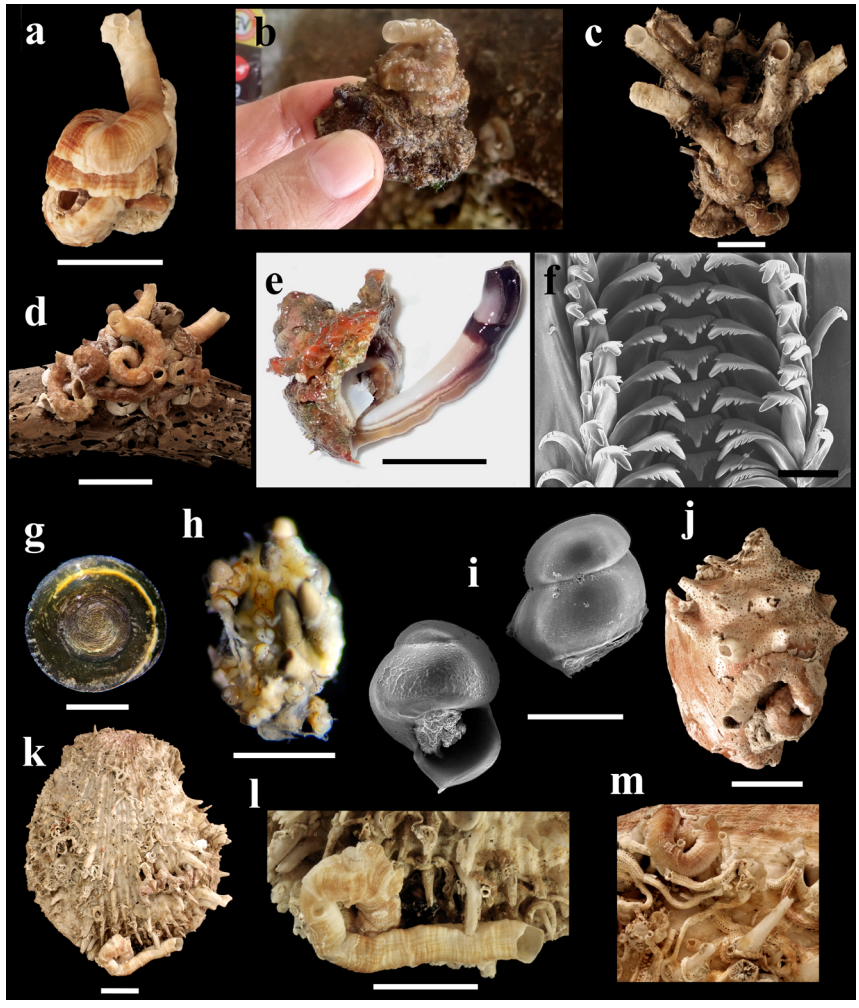

Figure 2. *Eualetes tulipa.* **a.** A specimen attached to a barnacle and bivalve shell (INV MOL12713). **b.** Fresh specimen, Caño Dulce, Nov 2, 2024. **c.** Several aggregated specimens (INV MOL12706). **d.** Several specimens attached to woody debris (INV MOL12713); also juveniles are observed. **e.** Soft body (INV MOL12882). **f.** SEM radula (INV MOL12886). **g.** Operculum (INV MOL12881). **h.** An egg capsule containing embryos and pellets (INV MOL12882). **i.** SEM details of two embryos in different views (INV MOL12882). **j.** Empty shell attached to *Strombus pugilis* shell (INV MOL12714). **k–l.** Empty shell attached to a left valve of *Spondylus americanus* (MOL-396). **m.** Empty shell attached to the right valve of *S. americanus* (MOL-396). Scale bars: a, c–e, j–l: 2cm; g–h: 2 mm; i: 250 µm; f: 150 µm

foot is generally purplish-red (**Figure 2 e**). The radula (**Figure 2 f**; specimen from lot INV MOL12886) is taenioglossate and typical of the family Vermetidae, consisting of seven teeth: one central (rachidian), one pair of lateral, and two pairs of marginal teeth. The operculum is circular and corneous (**Figure 2 g**). Some individuals were found with attached egg masses with pellets (**Figure 2 h**). The shells of intracapsular juveniles are

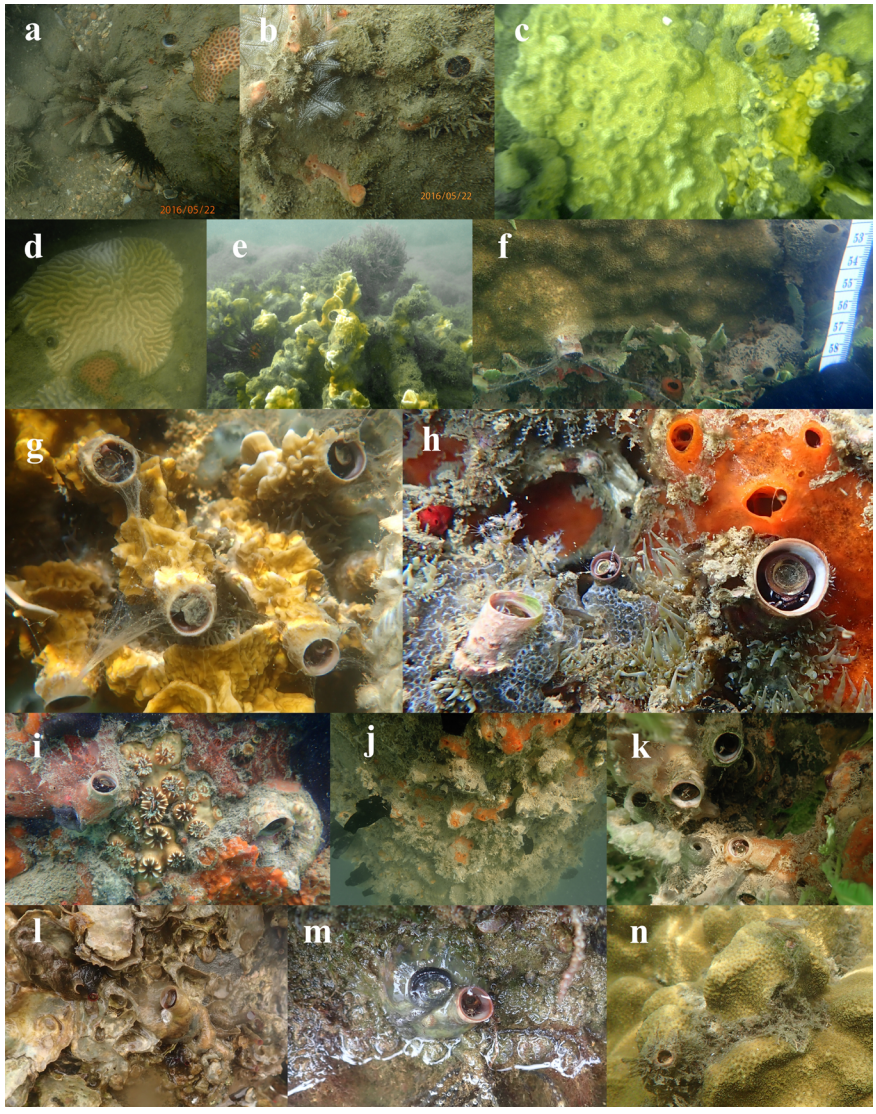

Figure 3. Field photographic information showing the presence of *Eualetes tulipa* from 2016 to 2024 in several substrates and localities of the Central Colombian Caribbean. **a., b.** Specimens on natural substrate (Puerto Caimán, 22/May/2016). **c.** Specimens on a natural substrate close to *Porites astreoides* Lamarck, 1816 colony and on *Millepora* sp. colony (Puerto Caimán, 29/Jul/2017). **d.** Solitary animal on *Pseudodiploria clivosa* (Ellis & Solander, 1786) colony (Puerto Caimán, 21/Feb/2019). **e.** Solitary animal on *Millepora* sp. colony (Puerto Caimán, 29/Jul/2017). **f–i.** Several specimens (PVm) on artificial substrate (concrete walls): **f.** Close to *P. astreoides* colony (18/May/2019), **g.** Between *Millepora* sp. colony (01/Nov/2025), **h.** Surrounded by *Exaiptasia diaphana* (Rapp, 1829) sea anemone, colonial ascidians, and a sponge (16/Aug/2025), **i.** Close to *Phyllangia americana americana* Milne Edwards & Haime, 1849 colony (18/May/2019). **j–k.** Several specimens (PVm, 27/Jun/2024) on an artificial substrate (metallic pillar): **k.** Detail. **l.** Several specimens (PVm, 27/Jun/2024) close to oysters on metallic pillar; juveniles also are observed. **m.** Specimen on natural rock (Caño Dulce, 12/Jun/2024). **n.** Specimen observed on *P. astreoides* colony (Isla Arena, 1/Jun/2019).

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globose, translucent, with approximately one and a half whorls, a distinctly marked brown suture, and a light-brown overall coloration (**Figure 2 h–i**). The soft parts of the juveniles are light yellow, with two black eye spots visible through the shell. These characteristics match the description provided by **Spotorno-Oliveira *et al*.** (2018).

Habitat-Ecology: The Colombian specimens were found attached to a gastropod (**Figure 2 j**) and bivalve shells (**Figure 2 k–m**), woody debris (**Figure 2 d**), natural rocks and corals (**Figure 3 a–e, m–n**). In artificial substrates, the specimens were observed on the vertical concrete walls (**Figure 3 f–i**) and metallic pillars (**Figure 3 j–k**) of an international marina (PVm) and a shipwreck. The specimens observed in PVm and Puerto Caimán were associated with a wide variety of sessile organisms, including sponges, cnidarians, ascidians (**Figure 3 c–k**), bivalves (**Figure 3 l**), barnacles, bryozoans, and other mobile animals. Notably, polychaete annelids were found inhabiting the shell spaces of the collected specimens. In the field, the species characteristic mucous threads to collect suspended organic matter were observed (**Miloslavich *et al*.**, 2010) (**Figure 3 f–g**).

Evidence of *E. tulipa* presence in the Colombian Caribbean includes field photographs dating back to 2016 in two areas: Puerto Caimán (**Figure 3 a–b**, May 2016, natural habitat; **Figure 3 c**, July 2017, **Figure 3d**, February 2019, **Figure 3 e**, July, 2017), PVm (**Figure 3 f–l**), Caño Dulce (**Figure 3 m**) – Department of Atlántico and Isla Arena – Department of Bolívar (**Figure 3 n,** June 2019). However, the invasion likely began earlier, with shells documented from a northern area (El Rodadero - Santa Marta, Department of Magdalena) as early as 1998 (**Figure 2 k–m**), specifically on a shipwreck. This date is close to *E. tulipa*'s first documented record in the Caribbean Sea (Venezuela, 1992, but with collections since 1986) (**Miloslavich & Penchaszadeh,** 1992).

Globally, the species has been recorded associated with artificial substrates such as concrete pilings and walls, metal, and wood substrates, and attached to the walls of a power plant, but also in natural environments such as sandstone fringing reefs, rocky reefs, and mangrove roots (**Miloslavich & Penchaszadeh**, 1992; **Miloslavich *et al*.**, 2010; **Spotorno-Oliveira *et al.***, 2018).

Depth: In Colombia, the species was found from less than 0.5 m to 30 m. In other areas, it occurs from intertidal rock pools to depths of 16 m (**Miloslavich *et al.***, 2010; **Jebakumar *et al.***, 2015; **Spotorno-Oliveira *et al.***, 2018).

Distribution: *Eualetes tulipa* type locality is not clear; it is believed to be native to the Pacific of Panama since the illustrations of the *Vermetus tulipa* type material by Chenu (1843–1845), for which the type locality is unknown, agree with different specimens found in that region (**Keen**, 1971). **Keen** (1971) reported it as native to Panama Bay in the Pacific Ocean, and also in Costa Rica. Records as a non-native species include Hawaii, Florida, Venezuela, Brazil, India (**Miloslavich & Penchaszadeh**, 1992; **Jebakumar *et al*.**, 2015; **Spotorno-Oliviera *et al.***, 2018; **Skinner *et al.***, 2019), and Colombia (this study).

Molecular analysis: Seven of the eight samples were successfully sequenced. The closest match for all our vermetid sequences in the GenBank BLAST search was *E. tulipa*, with identity percentages ranging from 100% to 99.50%, and an average query cover of 98.14% ± 0.38 (GenBank accession number MW278108.1; USA: Hawaii; unpublished). The second closest match was also *E. tulipa*, with identity percentages ranging from 99.85% to 99.33% and the same mean query cover of 98.14% ± 0.38 (GenBank accession number MW278406.1; USA: Hawaii; unpublished) (**Table 1**).

Analysis

In the Colombian Caribbean, the Vermetidae family includes three genera: *Thylacodes* Guettard, 1770; *Petaloconchus* H. C. Lea, 1843, and *Dendropoma* Mörch, 1861. Currently, five species are recognized within this family: *Thylacodes decussatus* (Gmelin, 1791), previously classified as *Serpulorbis decussata* (See **Díaz & Puyana**, 1994); *Petaloconchus erectus* (Dall, 1888); *P. varians* (A. d'Orbigny, 1839); *Dendropoma corrodens* (A. d'Orbigny, 1841), previously known as *D. annulatus* (See **Díaz & Puyana**, 1994; **WoRMS**, 2025; accessed 30/May/2025), and *Petaloconchus* sp. 1 (See **Yidi & Sarmiento,** 2010).

A sixth name, *Vermetus irregularis* A. d'Orbigny, 1841, was previously identified by **Yidi and Sarmiento** [2010 as *D. irregularis* (A. d'Orbigny, 1841)]. However, based on the illustrated photograph (**Yidi & Sarmiento**, 2010: Fig. 357), the shell resembles *E. tulipa* (30 mm size, collected: Bahía Neguanje, Tayrona National Natural Park N11°19.246"; W74°04.564, depth: 10 m). According to **WoRMS** (2025; accessed 30/May/2025), *V. irregularis* is cataloged as an *inquirendum* taxon, a term in biological classification referring to a species of uncertain identity that requires further study. Consequently, the record of *V. irregularis* is considered uncertain in the list of Vermetidae species for the Colombian Caribbean and may instead support the presence of *E. tulipa* in the Santa Marta area.

The *Eualetes* genus comprises only two species, *E. centiquadrus* (**Valenciennes**, 1846), which has been reported in the Colombian and Mexican Pacific (**OBIS**, 2025), and *E. tulipa*, which is an epifaunal suspension-feeding species that uses mucous threads to collect suspended organic matter (**Miloslavich *et al*.**, 2010). The identification of these groups is difficult due to the great plasticity and variability of the shell, for which there must be an integration between the description of the shell and the soft body (**Spotorno *et al*.**, 2012; **Scuderi *et al*.**, 2017). It has even been documented that vermetids have a high probability of producing different morphotypes according to environmental conditions (**Scuderi *et al.***, 2017). However, no other species recorded in the Caribbean is close to *E. tulipa*. The size and ornamentation of the shell, together with the presence of the operculum in the collected specimen and those observed in the field, agree with those described for the genus *Eualetes* (Com. Pers. Dr. R. Bieler 2021) and differ from other genera already reported in the Colombian Caribbean, such as *Thylacodes* and *Dendropoma*.

The molecular analyses supported the morphological identification of *E. tulipa* in Colombia. The high sequence similarity between our specimen and *E. tulipa* sequences from Hawaii (100% and 99.50% identity; 98.14% query cover) strongly supports its identification as *E. tulipa*. Further comparisons with additional molecular markers and sequences from both native and introduced populations are necessary to better understand the species' invasion dynamics and dispersal routes, considering the possible role of transoceanic human-mediated transport in facilitating its introduction (e.g., via the Panama Canal).

The reproductive biology of *E. tulipa* is well-documented, as it is a dioecious species (**Miloslavich & Penchaszadeh,** 1992; **Miloslavich *et al*.**, 2010). Reproductive studies on *E. tulipa* in the southern Caribbean indicate that this species reproduces year-round, with females brooding up to 54 egg capsules, each containing approximately 290 eggs, of which about 190 develop into veliger larvae that settle within 24 hours of hatching (**Miloslavich & Penchaszadeh,** 1992). Given these reproductive dynamics, it is essential to monitor this species, which has largely gone unnoticed in the Colombian Caribbean. Its high reproductive rate poses a silent threat to native species and ecosystems.

Eualetes tulipa has been reported as a non-native and invasive species because it has a high capacity to establish and transport in different artificial substrates (concrete and metal), and it has a great adaptability to the environmental conditions of the medium it colonizes (**Spotorno-Oliviera *et al.***, 2018; **Skinner *et al.***, 2019; **Wells & Bieler**, 2020). These factors are corroborated by its presence in the PVm and surrounding areas, a region that experiences changes in salinity and is influenced throughout the year by high contributions of suspended material, which generate highly turbid water all year round, explained by the proximity to the Magdalena River.

The proposed vectors for the introduction of marine gastropod fauna in South America, as recorded by **Darrigran *et al.*** (2020), include aquaculture, zooculture, and ballast and ship´s hull (approx. 19%), while the origin of about 6% of the studied cases remains unknown. **Gracia and Rangel-Buitrago** (2020) highlighted anthropogenic litter as a potential vector that demands attention in the Colombian Caribbean. Records indicate that this is one of the current mechanisms used by organisms for rafting, enabling them to potentially reach and colonize new areas. The mechanism of introduction of *E. tulipa* is unknown; however, its anthropogenic dispersal in the Colombian Caribbean could have

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been facilitated through ballast water and by transport as fouling fauna in the vessels. The above takes into account that the Colombian Caribbean has ports and marinas that mobilize vessels of diverse origins, types, and sizes. Rafting cannot be ruled out, as this species is well adapted to adhering to various substrates. Debris, such as litter or wood, could also play a significant role in the local spread of the species.

Members of the Vermetidae family are increasingly becoming a focus of monitoring efforts within fouling communities on both artificial and natural substrates. In these environments, they appear to adapt and thrive remarkably well. Vermetid gastropods are common components of marine fouling communities in warm temperate and tropical waters and are often regarded as potentially invasive or having a high potential to become invasive (**Bieler *et al.***, 2017). This is exemplified by *Thylacodes vandyensis* Bieler, Rawlings and T. M. Collins, 2017, a recently described species from the Florida Keys. The authors suggest that this species is likely a recent arrival from Pacific waters, identifying it as potentially invasive.

The ecological and biological implications of *E. tulipa* in ecosystems are not yet fully understood. However, as an invasive species, it is believed that it may contribute to the displacement of native fauna. Besides, a study by **Hoecksema *et al.*** (2022) in Curaçao documented the presence of *Petaloconchus* sp., an unknown coral-dwelling worm snail, which appeared to cause damage to its coral hosts. The authors noted that coral-dwelling vermetids had not been previously recognized in the scientific literature, suggesting that they may have been recently introduced or simply overlooked. In this context, a similar association was observed in natural environments, such as Puerto Caimán (**Figure 3 c–e**), Isla Arena (**Figure 3 n**), and the PVm between *E. tulipa* and some corals identified on artificial substrates. In the PVm, the corals involved were small colonies (**Gracia *et al.***, 2021) (**Figure 3 f, g, i**). Unfortunately, the marina replaced its substrates at the end of 2019 and the beginning of 2020, leaving only the photographic records of some colonies. Besides, vermetids are known to serve as intermediate hosts for Spirochiidae blood flukes, which parasitize loggerhead turtles (*Caretta caretta* Linnaeus, 1758) (**Bieler *et al.***, 2017). This expands the scope of their impact on the marine environment.

The information about *E. tulipa* in the Colombian Caribbean highlights the urgent need to continue and enhance taxonomic efforts in diverse groups, such as mollusks, employing integrative taxonomy that incorporates molecular tools for species delimitation, particularly in cases of environmental challenges and/or complex taxonomic issues. Additionally, securing financial support from environmental and management entities is critical.

Conclusions

Eualetes tulipa has likely gone unnoticed as an invasive species in the Colombian Caribbean, yet its biological and ecological traits suggest a high invasive potential. This species shows strong reproductive capacity and adaptability to variable environmental conditions (such as salinity and turbidity). The species' confirmed presence in PVm and surrounding areas indicates that it is already established, although historically having been misidentified or overlooked, possibly confused with other vermetid species.

Accurate identification of *E. tulipa* requires an integrative taxonomic approach due to the shell plasticity characteristic of vermetids. Therefore, combining shell and soft body features with molecular tools is essential for proper species delimitation, especially in taxa with complex taxonomy and potential ecological impacts.

Although the exact introduction pathway of *E. tulipa* in the Colombian Caribbean remains unknown, maritime traffic (via ballast water or hull fouling) and anthropogenic rafting are likely contributors.

The spread of invasive vermetids, such as *E. tulipa*, poses ecological risks to benthic communities, including harmful interactions with coral species and potential implications for marine turtle megafauna, which highlights the urgent need to enhance monitoring of coastal infrastructure, establish baseline biodiversity records, and implement environmental policies to prevent further biological invasions.

Author contributions

AGC: project conceptualization and contribution of funds, fieldwork, laboratory activities, material identification, data analysis, and manuscript writing. APR: fieldwork, laboratory activities, material identification, data analysis, and manuscript writing. All authors read and approved the final manuscript.

Conflicts of interest

The authors declare that they have no conflict of interest.

Data availability

All data generated or analyzed during this study are included in this published article.

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